the application should compare the alternate system's theoretical response to the prescribed system's response.

(ii) *A technical description of the alternate system.* This section shall detail all of the hardware and software included in the alternate system. Dimensioned drawings, flow-charts, schematics, and component specifications shall be included. Any data manipulation (*i.e.* calculations) that the system performs shall be presented in this section.

(iii) *A description of the procedures used to operate the system including the level of training that an operator must have to achieve acceptable results.* This section of the application shall describe all of the installation, calibration, operation, and maintenance procedures in a step-by-step format. Note that empirical calibration with respect to another prescribed or approved measurement system is not acceptable. Calibration should be performed with NIST traceable standards, or equivalent national standards. Diagrams, schematics, and other graphics may be used to enhance the description.

(iv) *A comparison of results from the alternate system and from the prescribed system (or other system approved by the Administrator).* The two systems must be calibrated independently to NIST traceable standards or equivalent national standards for this comparison. While other statistical analyses may be acceptable, it is recommended that the comparison be based on a minimum of 7 collocated and simultaneous tests. This comparison shall be performed over the ''hot-start'' portion of the FTP test cycle. If the comparison is paired, it must demonstrate that the alternate system passes a two-sided, paired t-test described in this paragraph. If the test is unpaired, it must demonstrate that the alternate system passes a two-sided, unpaired t-test described in this paragraph. Other statistical criteria may be set by the Administrator. The average of these tests for the reference system must return results less than or equal to the applicable emissions standard. The t-test is performed as follows, where ''n'' equals the number of tests:

(A) Calculate the average of the alternate system results; this is A_{avg}.

(B) Calculate the average of the results of the system to which the alternate system was referenced; this is R_{avg}.

(C) For an unpaired comparison, calculate the ''n−1'' standard deviation for the alternate and reference averages; these are A_{sd} and R_{sd} respectively. A_{sd} must be less than or equal to R_{sd}. If A_{sd} is greater than R_{sd}, the Administrator will not approve the application.

(D) For an unpaired comparison, calculate the t-value:

$$t_{unpaired} = (A_{avg} - R_{avg})/((A_{sd}^2 + R_{sd}^2)/n)^{1/2}$$

(E) For a paired comparison, calculate the ''n−1'' standard deviation (squared) of the differences, d_i, between the paired results, where ''i'' represents the i^{th} test of n number of tests:

$$S_D^2 = (Sd_i^2 - ((Sd_i)^2/n))/(n-1)$$

(F)(*1*) For a paired comparison, calculate the t-value:

$$t_{paired} = (A_{avg} - R_{avg})/(S_D^2/n)^{1/2}$$

(*2*) The absolute value of t must be less than the critical t value, t_{crit} at a 90% confidence interval for ''n−1'' degrees of freedom. The following table lists 90% confidence interval t_{crit} values for n−1 degrees of freedom:

90% Confidence interval critical t values vs. n−1 degrees of freedom for a two-sided, paired t−test

n −1	t_{crit}
6	1.94
7	1.89
8	1.86
9	1.83
10	1.81
11	1.80
12	1.78
13	1.77
14	1.76
15	1.75
16	1.75
17	1.74
18	1.73
19	1.73
20	1.72

[66 FR 5168, Jan. 18, 2001]

§ 86.1306–96 Equipment required and specifications; overview.

(a) *Exhaust emission tests.* All engines subject to this subpart are tested for exhaust emissions. Petroleum-, natural gas-, liquefied petroleum gas-, and methanol-fueled Otto-cycle and diesel engines are tested identically with two exceptions. First, the systems used to measure hydrocarbon, nitrogen oxide, methanol, formaldehyde and particulate depend on the type of engine being tested; petroleum-fueled diesel engines require a heated, continuous hydrocarbon detector and a heated, continuous nitrogen oxide detector (see § 86.1310); methanol-fueled engines require a heated hydrocarbon detector, a methanol detector and a formaldehyde detector; either a heated or non-heated continuous hydrocarbon detector may be used with natural gas-fueled and liquefied petroleum gas-fueled diesel engines; gasoline-fueled, natural gas-fueled, liquefied petroleum gas-fueled and methanol-fueled Otto-cycle engines are not tested for particulate emissions (see § 86.1309). Second, if a gasoline-fueled and methanol-fueled engine is to be used in a vehicle equipped with an evaporative canister, the test engine must have a loaded evaporative canister attached for the exhaust emission test. Necessary equipment and specifications appear in §§ 86.1308, 86.1309, 86.1310 and 86.1311.

(b) *Fuel, analytical gas, and engine cycle specifications.* Fuel specifications for exhaust emission testing are specified in § 86.1313. Analytical gases are specified in § 86.1314. The EPA heavy-duty transient engine cycles for use in exhaust testing are described in § 86.1333 and specified in appendix I to this part.

[58 FR 16064, Mar. 24, 1993, as amended at 59 FR 48525, Sept. 21, 1994]

§ 86.1308–84 Dynamometer and engine equipment specifications.

(a) *Engine dynamometer.* The engine dynamometer system must be capable of controlling engine torque and rpm simultaneously over transient cycles. The transient torque and rpm schedules described in § 86.1333–84 and specified in appendix I ((f)(i), (2), and (3)) must be followed within the accuracy requirements specified in § 86.1341–84. In addition to these general requirements, the engine or dynamometer readout signals for speed and torque shall meet the following accuracy specifications:

(1) Engine speed readout shall be accurate to within ±2 percent of the absolute standard value, as defined in paragraph (d) of this section.

(2) Engine flywheel torque readout shall be accurate to either within ±3 percent of the NBS ''true'' value torque (as defined in paragraph (e) of this section), or the following accuracies:

(i) ±2.5 ft-lbs. of the NBS ''true'' value if the full scale value is 550 ft-lbs. or less.

(ii) ±5 ft-lbs. of the NBS ''true'' value if the full scale value is 1050 ft-lbs. or less.

(iii) ±10 ft.-lbs., of the NBS ''true'' value if the full scale value is greater than 1050 ft.-lbs.

(3) *Option:* Internal dynamometer signals (i.e., armature current, etc.) may be used for torque measurement provided that it can be shown that the engine flywheel torque during the test cycle conforms to the accuracy specifications in paragraph (a) of this section. Such a measurement system must include compensation for increased or decreased flywheel torque due to the armature inertia during accelerations and decelerations in the test cycle.

(b) *Cycle verification equipment.* In order to verify that the test engine has followed the test cycle correctly, the dynamometer or engine readout signals for speed and torque must be collected in a manner that allows a statistical correlation between the actual engine performance and the test cycle (See § 86.1341–84). Normally this collection process would involve conversion of analog dynamometer or engine signals into digital values for storage in a computer. The conversion of dynamometer or engine values (computer or other) that are used to evaluate the validity of engine performance in relation to the test cycle shall be performed in a manner such that:

(1) Speed values used for cycle evaluation are accurate to within 2 percent of the dynamometer or engine flywheel torque readout value.

(2) Engine flywheel torque values used for cycle evaluation are accurate to within 2 percent of the dynamometer or engine flywheel torque readout value.

(c) *Option:* For some systems it may be more convenient to combine the tolerances in paragraphs (a) and (b) of this section. This is permitted if the root mean square method (RMS) is used.